Fusion Bonding Recipes for Glass-Glass Nanofluidic Devices

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Motivation

Thermal fusion bonding is the most effective way to make all-glass micro- and nanoscale devices with homogenous surface composition.

Objectives

- Develop an efficient, reliable fusion bonding recipe for the glass-glass structured devices with patterned nanochannels (at 50 nm in depth).
- Investigate the effect of experimental parameters (temperature and pressure) behind the glass-glass bonding process.

Background Information

- Glass is a desired material in micro- and nanoscale device fabrication due to its optical clarity, chemical inertness and temperature stability.
- One of the most important applications for micro- and nanodevices is Lab-on-a-Chip(LOC) devices.
- Fusion (direct) bonding is the best approach to generate an enclosed channel with 4 chemically similar walls.
- Channel collapse/disfiguration are some challenges associated with fusion bonding.

Previously Reported Fusion Bonding Techniques

- Mao[1] achieved 90%-95% bonding area by:

→ Piranha for 10 mins.

→ 28% ammonium hydroxide at 50 ℃ for 30 mins.

→ Spin dry, align.

→ Press glass wafers with 5lb weights for a few hours.

→ 550 ℃ for 12~18h with ramp rate of 1.0~1.5 ℃/min and cool down rate of 1.5 - 2.5 ℃/min.

- Allen and Chiu's [2] found out that using calcium acetate removes a key bottleneck in fusion bonding.

→ Treatment with Alconox (0.5%) and calcium acetate (30 mM).

→ ~ 4 kg weight of polished alumina.

→ 100 ℃ (heat at 0.3 ℃/min).

→ 625 ℃ (heat at 4 ℃/min) hold for 1 h.

→ Cool to 50 ℃ (slower than 2 ℃/min).

Design & Methods

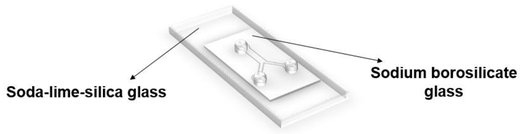


Figure 1. 3D view of the device

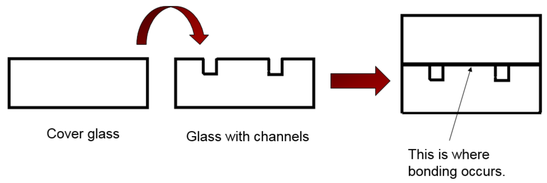


Figure 2. Schematics of fusion bonding

Experimental Procedures

1.Glass slides preprocessing.

(Cleaning and glass surface activation steps).

2.Slides assembly.

3.Programming set up and fusion bonding cycles.

4.Sample analysis.

(Leakage test; Bond stress and Optical properties).

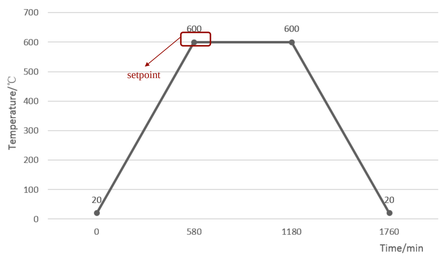
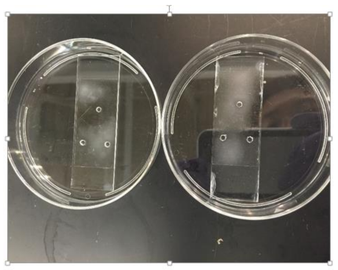
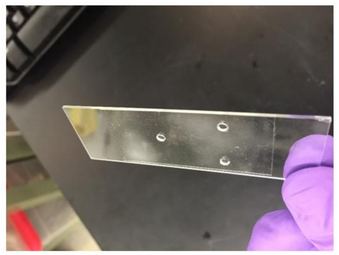


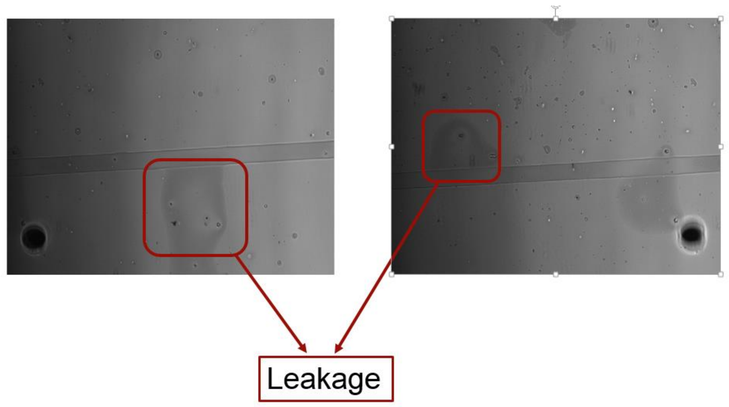
Figure 3. Example of heating profile used in fusion bonding.

Results





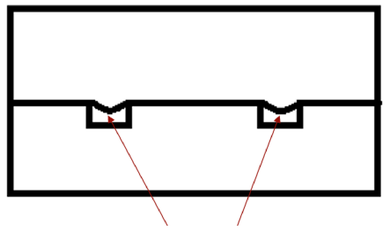
Actual device



Failure of the bonding

Successful parameters

- Setpoint temperature = 600℃.
- Time at setpoint temperature = 600 mins.
- Ramp up rate = Ramp down rate = 1 ℃/min.
- Applied pressure = 9.3 KPa.
- Calcium assisted surface activation.



Failure or collapse of the nanochannel fabrication (cross-sectional view).

Summary & Conclusions

- Our results indicate that sealed glass-glass channels can be bonded at a temperature of 600℃ over 10 hours along with simultaneous application of weight over the bonding area (a load of 1.14 kg corresponds to a pressure of 9.3 kPa applied over the entire area of the channel containing cover glass).
- Poor bonding is observed at lower set point temperature and when weight is not applied.
- Cracking of glass is seen when the load is increased.
- Our initial results showed that the use of calcium ion removes a key bottleneck in fusion bonding.

Future Work

1. Repeat ammonium hydroxide activation step [1] and calcium acetate activation [2].
2. Achieve fusion bonding for glass-glass nanofluidic devices with embedded metal electrodes.
3. Develop fusion bonding recipe for the glass-glass structured devices less than 50 nm in depth.

References

1.Mao, Pan, and Jongyoon Han. "Fabrication and characterization of 20 nm planar nanofluidic channels by glass–glass and glass–silicon bonding." Lab on a Chip 5.8 (2005): 837-844.

2.Allen, Peter B., and Daniel T. Chiu. "Calcium-assisted glass-to-glass bonding for fabrication of glass microfluidic devices." Analytical chemistry 80.18 (2008): 7153-7157.

Further Information

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Acknowledgements

The author would like to thank Kaushik Rangharajan and Emily Rosenthal-Kim for their help and guidance throughout the project.

The author would also like to thank my fellow MSNS lab mates, who have provided a lot of suggestions, constructive criticism, and encouragement.